Inefficiencies in the Mexican Peso-U.S. Dollar Exchange Rate Market: Is it Risk Premia or Irrationality?*

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Abstract

The efficiency of the peso-dollar exchange rate market is evaluated for the period 1997-2007. Considering the term structure of interest rates, this study finds that the efficient market hypothesis implied in the covered and uncovered interest parity fails to hold for the peso-dollar exchange rate market. With the help of survey data on peso-dollar exchange rate, deviations from efficiency are allocated to a risk premium e¤ect and expectational errors by the method developed by Frankel and Froot (1989). The results from this allocation indicate that the observed departures from efficiency in the peso-dollar exchange market capture both a time-varying risk premium and systematic errors in expectations. Risk premium induces investors to over-predict realized depreciation along the entire term structure; whereas, expectational errors exhibit a particular term structure. In the short-run, they lead to over-predict depreciation and in the long-run to under-predict it, counteracting the risk premium effect.

KEYWORDS: Efficient Market, Risk Premium, Expectational Errors, Survey Data.

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1 Introduction

The efficient market hypothesis establishes, in essence, that asset prices should fully reflect available information to market participants at every moment in time (Fama, 1970). This hypothesis possesses a relevant economic meaning since the price system, as a mechanism for communicating information, can act to coordinate the separate actions of different people who interact in a complex society (Hayek, 1945).

Academic interest in the specific case of foreign exchange market efficiency is related to arguments exploring the informational content of financial market prices and the implications of these arguments for social efficiency (Sarno and Taylor, 2002). The foreign exchange rate as a financial price is particularly important since it simultaneously affects the prices of all foreign assets, goods, and factors of production (Froot and Thaler, 1990). In this sense, a large amount of research for developed economies has found an apparent anomaly in the foreign exchange market since interest rate differentials and forward premia result in biased estimators of the actual exchange rate depreciation and thus lead to profitable opportunities of speculating based on available information to market participants.

Since the early 1990's, with the increasing financial liberalization and the transition to floating exchange rate regimes in emerging economies (Bekaert et al., 2002), the evaluation of exchange rate markets in developing countries appears to be an atractive field of research for extracting valuable lessons in understanding the economic sources behind the possible failures of foreign exchange market efficiency (Bansal and Dahlquist, 2000). Accordingly, this study examines the efficiency in the peso-dollar exchange market in Mexico for the period that spans from November 1997 to June 2007.

First, an evaluation of the hypothesis of market efficiency is performed by using the standard tests known as covered interest parity (CIP) and uncovered interest parity (UIP). This analysis takes into account the term structure of interest rates by evaluating the short-term horizons of 1, 3, and 6 months-ahead, as well as the medium-term horizons of 1 and 2 years-ahead. The econometric evidence of these tests suggests that the efficient market hypothesis implicit in the UIP condition fails to hold for the peso-dollar exchange rate market and, in contrast with the evidence for industrialized economies, CIP condition is rejected as well.

The previous evidence is analytically important since exchange rate market efficiency is assumed in virtually all of the prominent models of exchange rate determination and thus its frequent empirical rejection implies that these models are incomplete and therefore unusable in their current form (McCallum, 1992).

Lack of efficiency in foreign exchange markets is commonly attributed to evidence of a time-varying risk premium or to a violation of rational expectations. Most of the scholars have focused on the investors' risk aversion as an explanation of the UIP failure (Engel, 1995), while others argue the presence of systematic errors in agents' expectations as the principal cause of inefficiency (Bilson, 1981; Longworth, 1981). The central problem with these approaches is that the efficient hypothesis is a joint test of risk neutrality and rational expectations; therefore, without additional information one cannot address the source of the inefficiency directly. To avoid making assumptions about investors' risk aversion or about their expectations formation process, survey data on peso-dollar exchange rate expectations is employed according to the methodology developed by Froot and Frankel (1989). With the help of survey data one can allocate part of the deviation from efficiency to each of the alternatives: a time-varying risk premium and systematic expectational errors. The data on peso-dollar exchange rate expectations come from two surveys of professional forecasters: one conducted by the Bank of Mexico (for short-term forecast horizons), and another conducted by the private firm *Consensus Economics* (for medium-term forecast horizons).

The results from this allocation indicate that the observed departures from efficiency in the peso-dollar exchange market capture both a time-varying risk premium and systematic errors in the expectations formation process.

First, the analysis supports the already documented idea that the perception of the peso as a riskier currency *vís-a-vís* the dollar induces agents to over-predict the actual depreciation of the exchange rate as a compensation for investing in "risky" assets.

Second, the implemented analysis applied to multiple horizons shows that the systematic errors in expectations present a particular term structure. For short-term horizons (less than a year), expectational errors lead investors to over-predict actual depreciation and reinforce the risk-premium effect; whereas for longer horizons (1 and 2 years-ahead), deviations from rationality induce investors to under-predict actual depreciation and counteract the risk-premium effect.

Following this general introduction, the definition of foreign exchange market efficiency and its underlying assumptions are formalized in Section 2. Next, Section 3 focuses on the evaluation of the efficient market hypothesis through static and dynamic tests of CIP and UIP applied to multiple horizons. With the help of survey data, Section 4 separates the bias of the interest rate differential in a component attributable to risk premium and in a component attributable to systematic expectational errors. Section 5 summarizes the evidence presented. Finally, section 6 presents some concluding remarks.

2 Foreign Exchange Market Efficiency

The notion of market efficiency refers, in general, to those markets in which prices provide accurate signals for resource allocation (Fama, 1970). To accomplish this objective, asset prices should reflect information up to the point at which the marginal benefits of acting on the information do not exceed the marginal costs of collecting it.[1] Therefore, relevant information is not ignored in an efficient market rendering impossible for agents to obtain systematic economic benefits based on the available information set (Jensen, 1978).

The efficient market hypothesis for the exchange rate market can be reduced to a joint hypothesis that *i)* agents incorporate all available information to construct their exchange rate expectations and *ii)* agents are risk neutral in the sense that they are indifferent to assets with the same characteristics except for the denomination of the currency.

To indicate the assumptions underlying foreign exchange market efficiency, consider three strategies for investing peso funds in a particular period t. The first is to invest in a peso-denominated instrument with maturity in period $t+h$, and a rate of return denoted $1+i_t$. The second strategy is to convert pesos to dollars at the spot exchange rate S_t, invest in a dollar-denominated instrument with maturity in period $t+h$ and interest rate i_t^*, and convert back to pesos at maturity. The rate of return from this investment strategy is

$$\frac{S_{t+h} \cdot (1+i_t^*)}{S_t}.$$

This strategy involves foreign exchange risk because at period t one is uncertain about which is the spot rate h periods ahead, S_{t+h}. The third strategy differs from the second one in that it involves hedging against exchange rate risk by buying dollars forward at price $F_{t+h,t}$ in the same period t the pesos are converted to dollars. This hedged investment provides a sure return in pesos equal to

$$\frac{F_{t+h,t} \cdot (1+i_t^*)}{S_t}.$$

Therefore, if transactions costs are negligible; and underlying instruments are identical in terms of liquidity, maturity, and default risk, arbitrage requires that the rates of return of the strategies that involve no risk (i.e., the first and the third strategy) be the

[1] Since these benefits and costs differ between agents and are in general, unobservable, the specification of the agent's information set is, from the point of view of the researcher, intrisically arbitrary (Thomas, 1999).

same:

$$1 + i_t = \frac{F_{t+h,t} \cdot (1 + i_t^*)}{S_t}.$$

Taking logs of both sides and using the approximation $\log(1 + x) \approx x$, the covered interest parity (CIP) is obtained:

$$f_{t+h,t} - s_t = i_t - i_t^*, \tag{1}$$

where $f_{t+h,t} = \log(F_{t+h,t})$ and $s_t = \log(S_t)$.

The rate of return from the second strategy is uncertain due to the possible fluctuations in the exchange rate between periods t and $t + h$, but if investors are risk neutral, its expected return is equal to the sure rate of return from investing in a peso-denominated instrument (i.e., the first strategy). In addition, if their expectations are rational, the expected return is the conditional expectation based on the available information set Ω_t, such that

$$E\left[\frac{S_{t+h} \cdot (1 + i_t^*)}{S_t} \mid \Omega_t\right] = (1 + i_t).$$

Since S_t and i_t^* are known in period t, this equality can be reduced to

$$\frac{E\left[S_{t+h} \middle| \Omega_t\right]}{S_t} = \frac{1 + i_t}{1 + i_t^*}.$$

Again, by log approximation, this equality can be written as

$$\Delta s_{t+h,t}^e = i_t - i_t^*, \tag{2}$$

where $s_{t+h,t}^e = E[s_{t+h}|\Omega_t]$ and $\Delta s_{t+h,t}^e = s_{t+h,t}^e - s_t$.

This equation, known as uncovered interest rate parity (UIP) can be interpreted as saying that *"the expected gains from holding one currency rather than another must be just offset by the opportunity cost of holding funds in this currency rather than the other"* (Sarno and Taylor (2002), pp. 5).

3 An Efficiency Evaluation of the Peso-Dollar Exchange Rate

3.1 Covered Interest Parity (CIP)

For testing the validity of CIP, a regression of the forward premium $(f_{t+h,t} - s_t)$ on the interest rate differential $(i_t - i_t^*)$ inspired by equation (1) is estimated:

$$\begin{aligned} f_{t+h,t} - s_t &= \alpha_0 + \beta_0 (i_t - i_t^*) + u_t. \\ H_0 &: \alpha_0 = 0, \beta_0 = 1 \end{aligned} \tag{R.1}$$

As can be seen, if CIP holds, in the absence of transaction costs, the parameters α_0 and β_0 should not differ from zero and unity, respectively, and the regression error u_t should be zero on average, and non-autocorrelated, thus, $E[u_t] = 0$ and $Cov[u_t, u_{t-h}] = 0, \forall\ h > 0$. In the less strict case in which significant deviations of α from zero reflect non-zero transaction costs, β_0 should still not differ from unity.

The case where $\beta_0 > 1$ implies greater returns from speculating in the peso-dollar exchange rate market by converting pesos to dollars at the exchange rate S_t, buying a dollar-denominated instrument with interest rate i_t^* and then converting back to pesos at price $F_{t+h,t}$, than the sure return of investing in a peso-denominated instrument. Analogously, $\beta_0 < 1$ indicates that one can obtain greater returns from investing in a peso-denominated instrument than from speculating in the forward market.

3.2 Uncovered Interest Parity (UIP)

Under the assumption of rational expectations, expected exchange rate depreciation, $\Delta s^e_{t+h,t}$ must differ from the observed depreciation by a rational forecast error e_{t+h}, that incorporates information available between periods t and $t+h$; therefore, it is not correlated with the information set at period t, Ω_t, then:

$$\Delta s_{t+h} = \Delta s^e_{t+h,t} + e_{t+h}, \text{ where } E[e_{t+h} | \Omega_t] = 0$$

Substituing this equation in (2), one can test the UIP condition through a regression of the actual exchange rate depreciation as the dependent variable of the form:

$$\Delta s_{t+h} = \alpha_1 + \beta_1 (i_t - i_t^*) + \varepsilon_{t+h} \tag{R.2}$$
$$H_0 : \alpha_1 = 0, \beta_1 = 1$$

Under the null hypothesis, the interest rate differential is an unbiased estimator of the actual depreciation. Thus, in this case, the peso-dollar exchange rate is efficient in the sense that expected profits from speculating in the exchange rate market are equal to zero.

Specifically, the parameter α_1 seeks to capture any constant bias in the exchange rate depreciation forecast. On the other hand, cases where $\beta_1 < 1$ imply that any increases in the interest rate differential are associated with a less than equal peso depreciation against the dollar. In fact, $\beta_1 < 0$, as regularly found in the literature, implies that an increment in the interest rate differential is associated with a decrease in the actual peso depreciation against the dollar.[2] In any of these cases, one cannot distinguish what proportion of the interest rate differential bias is caused by irrationality in investors' expectations or by their deviations from risk neutrality.

3.3 Econometric Considerations

The parameters α_0 and β_0 from the CIP condition expressed in regression (R.1) can be consistently estimated by the Ordinary Least Squares method (OLS). Furthermore, this method offers efficient standard errors since the regression error u_t is spherical (i.e., $E[u_t] = 0$, $Var[u_t] = \sigma^2$ and $Cov[u_t, u_{t-h}] = 0$, $\forall\ h > 0$). However, in the case of the UIP condition expressed in regression (R.2), OLS is not optimal since under the null hypothesis of $\alpha_1 = 0$ and $\beta_1 = 1$, the regression error ε_{t+h} can be seen as a forecast error with an autocorrelation structure like that of a moving average of order $h-1$ (MA$(h-1)$) This serial correlation arises since the sample frecuency is lower than the maturity frecuency of the interest rates.

To efficiently estimate the UIP condition for the peso-dollar exchange rate market, one must model the presence of autocorrelation in the error process. For this reason, regression (R.2) is estimated through the General Method of Moments (GMM) proposed by Hansen (1982). With this technique, one can make an appropriate modification of the variance-covariance estimator in order to obtain efficient standard errors consistent

[2] If α_0 tends to zero, $\beta_1 < 0$ implies directly that a greater interest rate differential is associated with an expected peso appreciation against the dollar.

with autocorrelation of order $h-1$. Considering that, under the null hypothesis, the interest rate differential is orthogonal to ε_{t+h}, the same predetermined regressor $(i_t - i_t^*)$ is used as an instrument to estimate regression $(R.2)$.

3.4 Data

For the empirical tests of the CIP and UIP conditions for the peso-dollar exchange rate market, forward premia and interest rate differentials were constructed for the short-term horizons of 1, 3 and 6 months-ahead and for the medium-term horizons of 1 and 2 years-ahead. The frequency of observations is monthly, and each datapoint was constructed as the arithmetic mean of the observations at the close of each day as obtained from the Bloomberg Platform and Banco de México.

The data for the spot peso-dollar exchange rate is obtained from the database of Banco de México[3]. These rates are daily averages of quotes offered by major mexican banks and other financial intermediaries.

For the interest rate on peso-denominated assets, the TIIE rate available in the Bloomberg database was employed, an inter-bank rate constructed from the daily quotes of distinct Mexican banks.[4] The interest rate on dollar-denominated assets is calculated from the LIBOR rate obtained also from the Bloomberg database.

The forward quotes for peso-dollar exchange rates employed are obtained as the arithmetic mean from a sample of forward contracts held by distinct financial institutions in New York City as reported in the Bloomberg Platform.[5]

3.5 Evidence

Table 1 presents the empirical evidence of the CIP test on the peso-dollar exchange rate market through OLS estimation of regression (1).

To test the joint hypothesis of CIP, the next-to-the-last column of this table shows the Wald test statistics for the joint hypothesis of $\alpha_0 = 0$ and $\beta_0 = 1$ for each horizon under study. As can be seen, contrary to the documented evidence for industrialized economies, in the case of the peso-dollar exchange rate, one can reject (at the 1% level

[3] The ticker for the peso-dollar exchange rate from Banco de México database is SF329.

[4] The longer maturity term for the TIIE is 3 months. For this reason TIIE swap rates are employed instead to lenghten the yield curve. The *Bloomberg* tickers for the TIIE rate are: MXIBTIIE Index for 1 month and MXIB91DT Index pfor 3 months. The tickers for the TIIE swap rates are: MPSWF for 6 months, MPSW1 for 12 months and MPSW2 for 24 months.

[5] The Bloomberg tickers for the forward exchange rates used are: MXN1M for 1 month-ahead horizon, MXN3M for 3 months ahead, MXN6M for 6 months ahead, MXN12M for 1 year ahead, and MXN2Y for the 2 years-ahead horizon.

of statistical significance) the CIP condition in all horizons with the exception of 1 year-ahead.

The third column of table 1 shows that α_0 is statistically positive in the 2 years-ahead horizon, which can be seen as evidence of constant transaction costs that account for 8% in annual terms. However, even if constant transaction costs are not taken as evidence of inefficiency in this horizon, one can reject (at the 1% significance level) the null hypothesis of $\beta_0 = 1$ as shown in the last column of table 1.

Indeed, for short term horizons $\widehat{\beta}_0 > 1$, which is evidence that one can obtain greater returns from converting pesos to dollars in period t, invest the funds in a dollar-denominated instrument, and then convert back to pesos in the forward market, than just investing in a peso-denominated instrument. On the contrary, for the medium term horizon of 2 years-ahead, $\beta_0 < 1$, which can be interpreted as greater profitability from investing in a peso-denominated instrument, than speculating in the forward market.

Table 1: Test of CIP Condition on Peso-Dollar Exchange Rate Market

$$fp_{t+h,t} = \alpha_0 + \beta_0(i_t - i_t^*) + u_t$$

Horizon	Sample Period	$\widehat{\alpha}_0$	$\widehat{\beta}_0$	Adjusted R^2	Obs	χ^2 Test: $a_0 = 0, \beta_0 = 1$	n Test: $\beta_0 = 1$
1 month	Nov-97/June-07	0.000	1.154***	0.76	116	14.72***	2.01**
		(0.000)	(0.077)				
3 months	Nov-97/June-07	0.000	1.073***	0.95	116	20.09***	2.13**
		(0.001)	(0.034)				
6 months	Feb-00/June-07	-0.001	1.063***	0.97	89	25.13***	2.84***
		(0.001)	(0.022)				
1 year	Feb-00/June-07	0.000	0.999***	0.99	89	0.41	-0.09
		(0.001)	(0.013)				
2 years	Feb-00/June-07	0.008***	0.847***	0.99	89	653.68***	-15.17***
		(0.001)	(0.010)				

White's (1980) standard errors in parentheses

*, ** and *** denote statistical significance at the 10, 5 and 1 percent level, respectively.

The results of testing the peso-dollar UIP condition expressed in equation (R.2) through GMM estimation are shown in table 2. As in the case of the CIP results, the next-to-the-last column of this table shows the Wald test statistics for the joint hypothesis of $\alpha_1 = 0$ and $\beta_1 = 1$ for each horizon under study. The main result of this table is that the efficiency hypothesis can be rejected (at a 1% significance level) for the peso-dollar exchange rate market in all horizons with the exception of 1 year-ahead.

In addition, in those horizons where efficiency can be rejected, the coefficients associated with the interest rate differential $(i_t - i_t^*)$ are statistically different from 1. From these coefficients one can observe that the interest rate differential bias changes with the forecast horizon. Thus, investors in the peso-dollar exchange rate market tend to over-predict realized depreciation for horizons less than a year and to under-predict it for the 2 years-ahead horizon.

In fact, the evidence for 1 and 2 years-ahead horizons differs with the empiric regularity encountered in industrialized economies where $\widehat{\beta}_1$ is found to be near zero or negative for all horizons examined. In this sense, Froot and Thaler (1990) report that the average value of $\widehat{\beta}_1$ amongst 75 published papers is around -0.88 (the authors do not report a standard error).

Table 2: Test of UIP Condition on Peso-Dollar Exchange Rate Market

$$\Delta s_{t+h} = \alpha_1 + \beta_1 (i_t - i_t^*) + \varepsilon_{1,t+h}$$

Horizon	Sample Period	$\widehat{\alpha}_1$	$\widehat{\beta}_1$	Adjusted R^2	Obs	χ^2 Test: $a_1 = 0, \beta_1 = 1$	n Test: $\beta_1 = 1$
1 month	Dec-97/June-07	0.004	-0.223	0.00	115	11.51***	-2.96***
		(0.003)	(0.412)				
3 months	Feb-98/June-07	0.013*	-0.231	0.01	113	16.91***	-3.71***
		(0.007)	(0.332)				
6 months	Ene-01/June-07	0.029	-0.572	0.03	78	12.96***	-2.99***
		(0.018)	(0.525)				
1 year	Apr-02/June-07	-0.025	0.927***	0.09	63	2.46	-0.22
		(0.025)	(0.337)				
2 years	Apr-03/June-07	-0.170**	1.615***	0.36	51	15.09***	1.74*
		(0.076)	(0.354)				

GMM Standard Errors with h-1 autocorrelation in parentheses.

*, ** and *** denote statistical significance at the 10, 5 and 1 percent level, respectively.

The evidence presented does not seem to depend on the sample size across horizons. If the exercise is repeated on a common sample between horizons (April-03/June-07), the same results remain (results not reported).

In summary, with the exception of the 1 year-ahead horizon, the peso-dollar exchange rate market seems to be inefficient in the sense that, probably, the expected profit of arbitraging in this exchange rate market may be positive.

Besides assessing the peso-dollar exchange rate efficiency for the entire sample period, one must also acknowledge the evolution of the CIP and UIP parameters through time in order to control for possible structural breaks that may have ocurred during the period under consideration. Among the examples of structural breaks thay may have affected the peso-dollar UIP condition are the adoption of an inflation targeting regime in January 2001 and the change from a non-borrowed reserves target to an interest rate target as the monetary policy instrument of the central bank in April 2004. In this regard, figure 1 and 2 show the evolution of the CIP and UIP estimators derived from rolling-window regressions, along with 90% confidence intervals for the apparent efficient horizon of 1 year-ahead.[6]

First, figure 1 presents evidence that both the coefficient associated with constant transaction costs, and the one associated with the interest rate differential were statistically different from zero and unity, respectively, through the year 2006. This additional evidence of inefficiency in some periods cannot be detected with the static regressions from table 1, that indicates that the CIP condition holds, on average, for the 1 year-ahead horizon.

Second, figure 2 shows that the variablity in the UIP estimators appears to be considerably larger than that of the CIP condition. Indeed, persistent deviations from efficiency arise when time-varying parameters are estimated. In particular, for the first half of the sample, $\widehat{\beta}_1$ locates statistically below zero. Then, from 2005 to 2006, this estimator does not differ statistically from 1, and finally, tends to zero by the end of the sample at a 90 percent level of confidence.

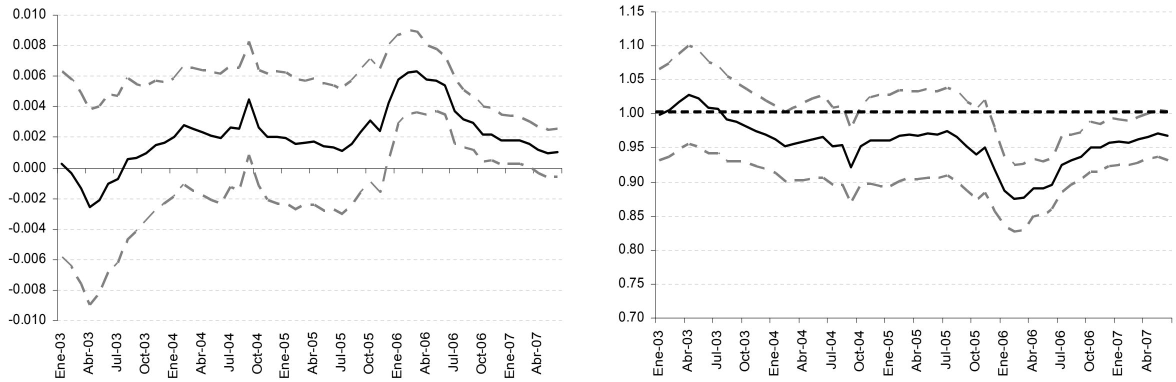
This evidence of the lack of efficiency of the peso-dollar exchange rate market in some sample periods for the 1 year-ahead horizon cannot be acknowledged with the static estimations presented in table 2, in which, on the average, the UIP condition seems to hold.

4 Is it a Risk Premia or Irrationality?

Once the inefficiencies in the peso-dollar exchange rate market have been accounted for, the next natural step is to question whether these anomalies are due to a time-varying risk premium or are the result of systematic expectational errors from investors or both. In this sense, previous research by Frankel and Froot (1987) and Froot and

[6] Each estimation window consists of 36 observations (3 years), but the qualitative results are not affected if 1 or 2 years windows are estimated instead.

Figure 1: Rolling CIP Estimates for h=1 year-ahead



Parameter α_0 Parameter β_0

*Confidence Interval at the 90 percent level of confidence with White's (1980) Standard Errors.
*Each date denotes last observation for each rolling-window of 36 months (3 years).

Figure 2: Rolling UIP Estimates for h=1 year-ahead

Parameter α_1 Parameter β_1

*Confidence Interval at the 90 percent level of confidence with GMM Standard Errors with h-1 autocorrelation.
*Each date denotes last observation for each rolling-window of 36 months (3 years).

Frankel (1989) show that exchange rate forecasts obtained from survey data provide an adequate measure of exchange rate expectations so that the researcher can empirically separate the interest rate differential into its main components (expected depreciation and risk premium), without the need of assuming either the investors type of risk aversion or its rationality. Accordingly, the UIP condition can be re-written:

$$\Delta s^e_{t+h,t} + \rho_t = i_t - i^*_t, \tag{3}$$

where ρ_t denotes a risk premium for holding peso-denominated assets relative to dollar-denominated assets.

Following Froot and Frankel (1989) and using equation (3), the probability limit of the coeffcient β_1 is:

$$\beta_1 = \frac{cov(i_t - i^*_t, \Delta s_{t+h})}{var(i_t - i^*_t)}$$

This coefficient can be algebraically arranged:

$$\beta_1 = 1 - \beta_{rp} - \beta_{re},$$

$$\beta_{rp} = \frac{var(\rho_t) + cov(\Delta s^e_{t+h,t}, \rho_t)}{var(i_t - i^*_t)} \text{ and } \beta_{re} = -\frac{cov(i_t - i^*_t, \varepsilon_{t+h})}{var(i_t - i^*_t)}.$$

In this way, one can write β_1 as equal to the null hypothesis of efficiency ($\beta_1 = 1$) minus deviations from the assumptions that *i)* agents are risk neutral (β_{rp}) and *ii)* agents form their expectations rationally (β_{re}).

Consequently, if $\beta_{rp} = 0$, one can conclude that there is no risk premium or if it exists is uncorrelated with the interest rate differential. In the same manner, if there are no systematic errors in the sample or if they are not related to the interest rate differential, then $\beta_{re} = 0$.

4.1 Survey Data of Professional Forecasters

To obtain measures of the expected depreciation of forecasters we employ two sources. First, for the 1, 3, and 6 months-ahead horizons, the Survey Professional Forecasters (SPF) maintained by Banco de México is used.

The SPF is conducted by Banco de México on a monthly basis since September 1994. Nowadays, the SPF covers around 20 macroeconomic variables related to investment, production, labor markets, public finance and international trade. In addition, the survey asks the external forecasters for their views on some qualitative aspects of the Mexican economic environment.

The number of forecasters in the survey has varied over the years, with less than 15 respondents in the earlier months, and approximately 30 regular respondents in recent surveys. The specialists who participate in the survey come mainly from commercial banks and other financial institutions (57%), followed by consulting firms (29%) and industrial and academic institutions (14%) in a smaller proportion. Their forecasts are gathered by mail on the second half of each month and the un-weighted mean (consensus forecast) is published monthly by Banco de México in a detailed report that contains the evolution of these expectations.

Data on 1 and 3 months-ahead peso-dollar exchange rate forecasts are available from this survey since November 1997 and for the 6 months-ahead horizon since July 2000.

Table 3: Two Different Measures of Exchange Rate Expectations

Horizon	Period	Obs	μ de $\Delta\widehat{s}^e_{t+h,t}$	μ de $(i_t - i^*_t)$	μ de Δs_{t+h}
1 month	Dec-97/June-07	115	9.41	8.42	2.80
3 months	Feb-98/June-07	113	7.39	8.77	3.01
6 months	Agust-00/June-07	83	5.07	5.90	2.08
1 year	Feb-01/June-07	70	4.04	5.58	2.23
2 years	Feb-02/June-07	58	3.93	5.81	2.70

*Data expressed in annualized returns obtained by multiplying the log differences by 1200/h.
where h denotes the forecast horizon.
**μ symbol denotes sample mean

Due to the lack of data for longer horizons in the SPF, forecasts for 1 and 2 years-ahead horizons are obtained from the Latin American issues of *Consensus Forecasts*. Each month, *Consensus Economics* collects the forecasts from a number of financial institutions and professional forecasters from 7 Latin American countries: Argentina, Brazil, Chile, Colombia, Mexico, Peru and Venezuela. This survey collects data on the peso-dollar exchange rate since December 1997; however, data on a monthly basis is available since April 2001.

Both surveys report consensus forecasts, constructed as the mean across forecasters. The average number of forecasters in the SPF and *Consensus Forecasts* are 30 and 18, respectively. One should point out that the usual respondents in the *Consensus Forecasts* survey are included as well in the SPF; hence, one may regard the later as a subset of the survey maintained by Banco de México, thus comparison between both data seems possible.

Table 3 shows the mean values of expected peso-dollar exchange rate depreciation obtained from survey data against the implicit depreciation in the interest rate differential. For comparison purposes, the last column of table 3 also exhibits the realized depreciation for each horizon under study.

From these descriptive statistics, a positive relationship between the survey expected depreciation and the market expected depreciation (interest rate differential) is evident, since in those horizons selling forward at a smaller discount, professional forecasters expect a smaller peso depreciation against the dollar. On the other hand, both measures of expected exchange rate depreciation, consistently over-predicted, on the average, realized depreciation. However, this over-prediction is smaller in survey data.

4.2 Risk Premium as an Explanation of the Inefficiency

A similar econometric approach as the one used to test for the UIP hypothesis can be performed to assess whether a time-varying risk premium is correlated with the interest rate differential in the peso-dollar exchange rate market. Thus, if surveys measure the investors' expected depreciation with some degree of measurement error that we assumed to be randomly distributed with zero mean, then survey expected depreciation can be written:

$$\Delta \widehat{s}^e_{t+h} = \Delta s^e_{t+h} + \eta_{t+h},$$

Δs^e_{t+h} is the non-observable expected exchange rate depreciation, $\Delta \widehat{s}^e_{t+h}$ is the survey expected depreciation, and η_{t+h} is a classical measurement errror with $E\left[\eta_{t+h}|\Omega_t\right] = 0$.

Now, substituing $\Delta \widehat{s}^e_{t+h}$ in (R.2) one can obtain:

$$\begin{aligned} \Delta \widehat{s}^e_{t+h} &= \alpha_2 + \beta_2 (i_t - i^*_t) + \eta_{t+h}. \\ H_0 &: \alpha_2 = 0, \beta_2 = 1 \end{aligned} \quad (4)$$

Using the definition of β_{rp}, $\beta_2 = 1 - \beta_{pr}$. Therefore, the cases in which $\beta_2 = 1$ imply that no correlation between a risk premium and the interest rate differential exists, and one cannot attribute ineficiencies in the peso-dollar exchange rate market to a time-varying risk premium.

In addition, the existence of a constant risk premium can be tested from regression (4) when coefficient α_2 differs statistically from zero.

Another way of interpreting the coefficient β_2 is thinking of regression (4) as a UIP version without the restrictive assumption of rational expectations. Thus, if $\beta_2 = 1$, peso-denominated assets and dollar-denominated assets can be regarded as perfect substitutes in investors portfolios.

The results of estimating regression (4) for each horizon by GMM are shown in table 4.

Table 4: Test of the Presence of Risk Premium

$$\Delta\widehat{s}^{e}_{t+h} = \alpha_2 + \beta_2(i_t - i^*_t) + \eta_{t+h}$$

Horizon	Period	$\widehat{\alpha}_2$	$\widehat{\beta}_2$	Adjusted R^2	Obs	χ^2 Test: $a_2 = 0, \beta_2 = 1$	n Test: $\beta_2 = 1$	n Test: $\beta_2 = 0.5$
1 month	Dec-97/June-07	0.003** (0.001)	0.700*** (0.215)	0.13	115	5.26*	-1.40	0.93
3 months	Feb-98/June-07	0.006* (0.004)	0.552*** (0.172)	0.23	113	7.87**	-2.60***	0.30
6 months	Jan-01/June-07	0.004 (0.007)	0.690*** (0.242)	0.18	78	2.99	-1.28	0.78
1 year	Apr-02/June-07	0.026 (0.018)	0.147 (0.316)	0.00	63	13.82***	-2.70***	-1.12
2 years	Apr-03/June-07	0.018 (0.019)	0.353** (0.163)	0.10	51	63.11***	-3.96***	-0.90

GMM Standard Errors with h-1 autocorrelation in parentheses.

*, ** and *** denote statistical significance at the 10, 5 and 1 percent level, respectively.

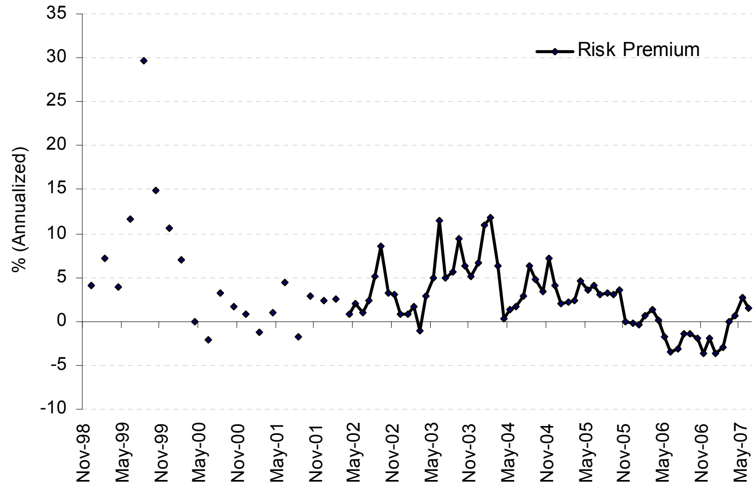
The last column of table 4 (n test) presents the results of the hypothesis test that $\beta_2 = 0.5$. That this test cannot be rejected for all horizons examined, implies the existence of a time-varying risk premium for holding pesos that leads to over-prediction of the peso-dollar exchange rate depreciation for all horizons.

On the other hand, a constant risk premium component seems to play a role in the shorter horizons of 1 and 3 months-ahead, as $\widehat{\alpha}_2$ is statistically greater than zero with a magnitude of 3.6 and 2.4 percent in annual terms, respectively.

Finally, only for the 6 months-ahead horizon one can find evidence of perfect substitution between dollar-denominated and peso-denominated assets, since the null hypothesis of $\alpha_2 = 0$ and $\beta_2 = 1$ cannot be rejected at significant statistical levels.

Figure 3 show the risk premium implicit in survey expectations, taking the 1 year-ahead horizon as an example. Consistent with the econometric results, risk premium

Figure 3: Implied Risk Premium in Survey Data, $h = 1$ year.



*Dotted segment refers to the period from December 1997 to April 2001 in which Consensus. Forecasts Data was collected on a bimonthly basis.

appears to vary over time and is positive, on average, in the sample examined (around 3.6% annualized) contradicting the apparent efficiency when estimating the UIP condition. In fact, this risk premium for investing in peso-denominated funds takes values close to 30% annualized in the midst of the Asian and Russian crises during 1999.

4.3 Irrationality as an Explanation of the Inefficiency

To test formally for the existence of systematic errors in the exchange rate expectations of inverstors, one can employ the common result, under mean squared error loss, that a rational forecast error cannot be predicted with the information set available at period t, $E\left[\widehat{s}^e_{t+h,t} - s_{t+h}|\Omega_t\right] = 0$. Thus, in order to acknowledge whether investors predict the peso-dollar exchange rate depreciation by using available information in an efficient manner one can estimate the following regression:

$$\begin{aligned} \widehat{s}^e_{t+h,t} - s_{t+h} &= \alpha_3 + \beta_3(i_t - i^*_t) + \upsilon_{t+h}. \\ H_{0:}\ \alpha_3 &= 0,\ \beta_3 = 0, \end{aligned} \tag{5}$$

$\widehat{s}^e_{t+h,t} - s_{t+h}$ is the forecast error obtained from survey data. Under the null hypothesis, the error term, υ_{t+h}, is the classical measurement error from surveys minus the rational forecast error, ε_{t+h}, that captures any unexpected change in the exchange rate between periods t and $t+h$. Consequently, $\upsilon_{t+h} = \eta_{t+h} - \varepsilon_{t+h}$, with $E[\upsilon_{t+h}|\Omega_t] = 0$.

The hypothesis of rational expectations is fulfilled when $\alpha_3 = 0$ and $\beta_3 = 0$. Those cases where β_3 is different from zero are signs that investors are not efficiently incorporating the already known interest rate differential in their expectations of the peso-dollar exchange rate depreciation. Specifically, if $\beta_3 > 0$, an increase in the observed interest rate differential is associated with an over-prediction of the exchange rate depreciation and viceversa.

In the context of the interest rate differential coefficient (i.e., β_2), parameter β_3 becomes relevant since this coefficient is precisely equal to the deviation of efficiency due to systematic expectational errors, β_{re}.

Table 5: Test of Rational Expectations

$$\widehat{s}^e_{t+h,t} - s_{t+h} = \alpha_3 + \beta_3(i_t - i^*_t) + \upsilon_{t+h}$$

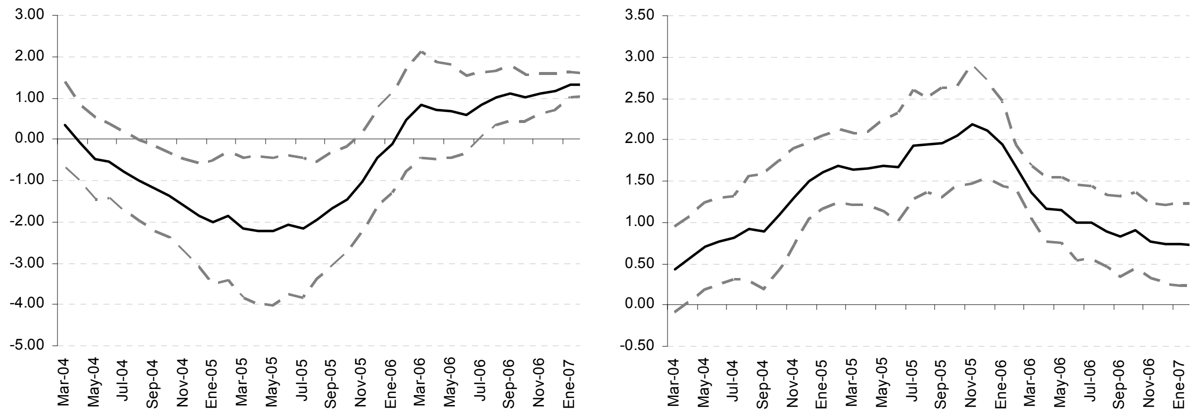
Horizon	Period	$\widehat{\alpha}_3$	$\widehat{\beta}_3$	Adjusted R^2	Obs	χ^2 Test: $a_3 = 0, \beta_3 = 0$	n Test: $\beta_3 = 1$	n Test: $\beta_3 = 0.5$
1 month	Dec-97/June-07	-0.001 (0.003)	0.923*** (0.319)	0.05	115	16.05***	-0.24	1.32
3 months	Feb-98/June-07	-0.007 (0.008)	0.783** (0.365)	0.08	113	6.01**	-0.60	0.77
6 months	Jan-01/June-07	-0.025 (0.020)	1.263** (0.626)	0.10	78	4.76*	0.42	1.22
1 year	Apr-02/June-07	0.055** (0.026)	-0.852** (0.375)	0.06	63	5.99**	-4.94***	-3.60***
2 years	Apr-03/June-07	0.173** (0.076)	-1.153*** (0.354)	0.21	51	23.43***	-6.08***	-4.67***

GMM Standard Errors with h-1 autocorrelation in parentheses.

*, ** and *** denote statistical significance at the 10, 5 and 1 percent level, respectively.

Table 5 reports the results of estimating regression (5) through the GMM method. The validity of assuming rational expectations for the peso-dollar exchange rate market (χ^2 test) does not hold for any of the horizons examined at a 90 percent level of confidence. In addition, for short-term horizons (less than a year), β_3 seems to be located between 0.5 and 1. For these cases, the expectational errors of investors induce a downward bias on the UIP coefficient (β_1). For 1 and 2 year-ahead horizons, β_3 is not statistically different from -1; thus, the inefficiency of investors to incorporate information contained in the interest rate differential for longer horizons tends to bias upwards the UIP coefficient.

Figure 4: Rolling β_{re} and β_{rp} estimates for $h = 1$ year-ahead



Parameter β_{re} Parameter β_{rp}

*Confidence Interval at the 90 percent level of confidence with GMM Standard Errors with h-1 autocorrelation.
*Each date denotes last observation for each rolling-window of 36 months (3 years).

4.4 Deviations from Efficiency in a Dinamic Perspective

An analysis of the evolution of efficiency deviations across time can be found through rolling windows estimations as those presented in section 3. For simplification purposes the evolution of β_{rp} and β_{re} parameters is presented only for the 1 year-ahead horizon (figure 4).

From this figure, one can see that the inverse relationship between β_{rp} and β_{re} established in the static exercises, lasts until 2006. Accordingly, in this period, expectational errors induced an under-prediction of the exchange rate depreciation; whereas, risk premium led to over-predicting it . However, from January 2006 to date, both efficiency deviations appear to be contributing, recently, to over-prediction of the peso-dollar exchange rate depreciation.

5 Further Discussion

Once the exchange rate market efficiency hypothesis has been evaluated on a developing economy like Mexico's and a characterization of the efficiency deviations in the form of failures in its main assumptions has been implemented, new lessons can be learned regarding exchange rate markets efficiency apart from the usual stories coming from the industrialized world. In general, this research shows that both risk premia and expectational errors of investors might play a fundamental role in explaining exchange rate market inefficiency. In line with the literature on developed economies, the presence of risk premia in the peso-dollar exchange rate market leads investors to over-predict realized depreciation at every horizon. In contrast with existing literature, a term structure of the expectational errors is found for the peso-dollar exchange rate market. In this sense, investors in this market tend to over-predict exchange rate depreciation in short-term horizons (less than a year), reinforcing the risk premium effect; whereas, systematic expectational errors lead investors to under-predict realized exchange rate depreciation in longer horizons (1 and 2 years-ahead), counteracting the risk premium effect.[7]

Table 6 summarizes the evidence already presented regarding the coefficient magnitude of the deviations from efficiency in the peso-dollar exchange rate market.

As can be observed from this table, the over-prediction of peso-dollar exchange rate depreciation in short-term horizons (less than a year) is mainly due to expectational errors and to a lesser extent to a risk premium effect.

Table 6: Components of the Failure of UIP

Horizon	Period	Obs	Failure of Rational Expectations β_{er}	Existence of Risk Premium β_{pr}	Implied Coefficient $1-\beta_{er}-\beta_{rp}$
1 month	Dec-97/June-07	115	$0.92^{\dagger}$	$0.30^{\dagger}$	-0.22
3 months	Feb-98/June-07	113	$0.78^{\dagger}$	$0.45^{\dagger}$	-0.23
6 months	Agust-00/June-07	83	$1.26^{\dagger}$	$0.31^{\dagger}$	-0.57
1 year	Feb-01/June-07	70	$-0.85^{\dagger}$	$0.85^{\dagger}$	1.00
2 years	Feb-02/June-07	58	$-1.15^{\dagger}$	$0.65^{\dagger}$	1.51

† denotes the estimate is different from zero (p<0.10).

However, for the 1 year-ahead horizon, the UIP condition seems to hold on the average. The results of separating the efficiency hypothesis into its main components

[7] This expectational errors term structure does not seem to depend on whether the SPF survey or the *Consensus Forecasts* data are employed.

Even though, *Consensus Forecasts* was used for 1 and 2 years-ahead horizons, a replication of the regressions was made for the 3 months-ahead horizon in which both surveys report peso-dollar exchange rate expectations.

The evidence from this exercise (not reported) shows that the qualitative results do not differ from those presented in the document, since both, β_{rp} and β_{re} do not differ statistically from 0.5, so that the evidence from the *Consensus Forecasts* survey can be regarded as a subset of the SPF.

imply the existence of deviations caused by a risk premium and by systematic expectational errors that have the same magnitude, but different signs, which in turn, nullify each other. For the 2 years-ahead horizon, the bias to under-predict exchange rate depreciation caused by systematical expectational errors seems to dominate, on average, the over-prediction triggered by the risk premium.

6 Conclusion

The results from the allocation of observed departures from efficiency capture both a time-varying risk premium and systematic errors in expectations. In this respect, the implied risk premium risk induces investors to over-predict realized depreciation along the entire term structe analyzed. On the other hand, the systematic expectational errors lead to over-predict realized depreciation for short-term horizons and to under-predict in the long-run.

Even though the presence of systematic expectational errors in the peso-dollar exchange rate market may be associated with irrational expectations, these biases could be consistent as well with learning processes in which rational agents are acquiring knowledge about their environment and may be unable fully to exploit arbitrage opportunities that are apparent in the data *ex post*. Also, systematic biases on expectations as the ones presented in this study could be consistent with the presence of *"peso problems"* (Krasker (1980)). Thus, when market expectations of the future value of the exchange rate are not fulfilled, the realized value of the exchange rate systematically deviates from its expected value. This persistent deviation may cause interest rate differential to be a biased estimator of the exchange rate depreciation.

An alternative explanation of the deviations of the efficiency hypothesis besides the argument presented here could be associated with the idea that central banks tend to overreact to exchange rate fluctuations and use the interest rate as a monetary policy instrument to contain exchange rate movement. This overreaction induces a joint determination of expected depreciation and interest rate differential, and causes a simultaneity bias on the UIP condition (McCallum,1992). This idea should be explored in future research since in emerging markets as the one evaluated here, the lack of credibility on monetary policy is greater than in developed economies that possess a long history of floating exchange rate regimes and greater interest rate fluctuations (Calvo and Reinhart, 2002).

The presence of systematic errors in the expectations of investors has been documented in this study. However, the mechanisms through which expectations are constructed remain unknown. Considering the term structure of systematic expectational errors, one may conclude that these mechanisms differ between short and long-term horizons. Further research on modelling the expectations of investors in developing economies needs to be done in order to rationalize the biases documented in this analysis.

Clearly, when an expected depreciation measure as the one provided by survey data is used, one can avoid the usual practice of assuming *ex ante* rational expectations and therefore, infer from realized data what the investors were expecting, a practice that, as this paper has shown, could lead to inaccurate conclusions.

References

[1] Bekaert, Geert, Harvey Campbell and Robin Lumsdaine, 2002. "Dating the Integration of World Equity Markets", Journal of Financial Economics, Vol. 65, 203-247.

[2] Bansal, Ravi and Magnus Dahlquist, 2000. "The Forward Premium Puzzle: Different Tales from Developed and Emerging Economies", Journal of International Economics, Vol. 51, 1, 115-144.

[3] Bilson, John, 1981. "The "Speculative Efficiency" Hypothesis", The Journal of Business, Vol. 54, 3, 435-451.

[4] Calvo, Guillermo and Carmen Reinhart, 2002. "Fear of Floating", The Quarterly Journal of Economics, Vol. 117, 2, 379-408.

[5] Engel, Charles, 1995. "The Forward Discount Anomaly and The Risk Premium: A Survey of Recent Evidence", Research Paper, 5312, National Bureau of Economic Research.

[6] Fama, Eugene, 1970. "Efficient Capital Markets: A Review of Theory and Empirical Work", The Journal of Finance, Vol. 25, 2, 383-417.

[7] Fama, Eugene, 1984. "Forward and Spot Exchange Rates", Journal of Monetary Economics, Vol. 14, 3, 319-338.

[8] Frankel, Jeffrey and Kenneth Froot, 1987. "Using Survey Data to Test Standard Propositions Regarding Exchange Rate Expectations", The American Economic Review, Vol. 77, 1, 133-153.

[9] Frankel, Jeffrey and Kenneth Froot, 1990. "Chartists, Fundamentalists, and Trading in the Foreign Exchange Market", The American Economic Review, Vol. 80, 2, 181-185.

[10] Froot, Kenneth and Jeffrey Frankel, 1989. "Forward Discount Bias: Is it an Exchange Risk Premium?", The Quarterly Journal of Economics, Vol. 104, 1, 139-161.

[11] Froot, Kenneth and Richard Thaler, 1990. "Anomalies: Foreign Exchange", The Journal of Economic Perspectives, Vol. 4, 3, 179-192.

[12] Hansen, Lars, 1982. "Large Sample Properties of Generalised Method of Moments Estimators", Econometrica, Vol. 50, 1029-1054.

[13] Hayek, Friedrich, 1945. "The Use of Knowledge in Society", American Economic Review, Vol. 4, 519-530.

[14] Hodrick, Robert and Sanjay Srivastava, 1984. "An Investigation of Risk and Return in Forward Foreign Exchange", Journal of International Money and Finance, Vol. 3, 5-30.

[15] Jensen, Michael, 1978. "Some Anomalous Evidence Regarding Market Efficiency", Journal of Financial Economics, Vol. 6, 2/3, 95-101.

[16] Krasker, William, 1980. "The "Peso Problem" in Testing the Efficiency of Forward Exchange Markets", Journal of Monetary Economics, Vol. 6, 269-276.

[17] Koning, Camiel and Stefan Straetmans, 1997. "Variation in the Slope Coefficient of the Fama Regression for Testing Uncovered Interest Rate Parity: Evidence from Fixed and Time-Varying Coefficient Approaches", Documento de Investigación, 97-014, Tinbergen Institute.

[18] Longworth, David, 1981. "Testing the Efficiency of the Canadian-U.S. Exchange Market under the Assumption of no Risk Premium", The Journal of Finance, Vol. 36, 1, 43-49.

[19] McCallum, Bennett, 1992. "A Reconsideration of the Uncovered Interest Parity Relationship", Research Paper, 4113, National Bureau of Economic Research.

[20] Sarno, Lucio and Mark Taylor, 2002. *The Economics of Exchange Rates*, Cambridge University Press.